Draft Summary
National Earthquake Prediction Evaluation Council (NEPEC)
October 16-17, 2006, University of California, Riverside
Engineering Building Unit, Rm. 205-206

Attendees

Council Members
Dr. Jim Dieterich, University of California, Riverside (Chair)
Dr. Dave Applegate, USGS Reston (Co-chair)
Dr. William Ellsworth, USGS Menlo Park
Dr. David Jackson, University of California, Los Angeles *(October 16 only)*
Dr. Barbara Romanowicz, University of California, Berkeley
Dr. Bruce Shaw, Columbia University
Dr. Wayne Thatcher, USGS Menlo Park
Dr. Mary Lou Zoback, USGS Menlo Park
(Council members Göran Ekström, Jeroen Tromp, and Robert Wesson were absent)

Dr. Michael Blanpied, USGS, Reston (Executive Secretary)

Invited Speakers *(October 17 only)*
Ms. Nancy Baumgartner, USGS Reston
Dr. Mike Reichle, California State Seismologist and CEPEC Vice-Chair
Dr. Chris Wills, California Geological Survey
Dr. Tom Jordan, University of Southern California
Dr. Karen Felzer, Mendenhall Post-doc, USGS Pasadena
Dr. Ken Hudnut, USGS Pasadena

Monday, October 16th (Open Session)

NEPEC Chair Jim Dieterich called the meeting to order at 10:45 a.m. with welcoming remarks. Applegate thanked Dieterich for hosting the meeting at U.C. Riverside. Introductions and a review of the agenda followed. Dieterich emphasized his intention to minimize the use of call-ins for face-to-face meetings and encouraged all committee members to attend in person if possible. Applegate noted that council member Ray Weldon had resigned, citing the press of other business that prevented him from giving the council the attention he felt it required.

> ***Action Item (NEPEC members):*** Council members are asked to provide Applegate and Blanpied with their views on needed areas of expertise and regional representation given departure of Weldon and council focus. Individual names are also sought.

Discussion of "Terms of Engagement" Document

Council member Dave Jackson gave a presentation summarizing a draft document that he and Jeroen Tromp to set criteria for NEPEC taking up consideration of earthquake predictions. The document, which was requested at the previous NEPEC meeting, was circulated prior to this meeting along with comments provided by Caltech professor

emeritus and former NEPEC chair Clarence Allen[1]. The document defines what constitutes a scientific prediction and what information NEPEC would need as a basic for making a judgment. Placed on the council's website, the guidelines would provide the criteria for bringing a prediction to NEPEC's attention. The guidelines do not encompass the range of topics that the council may take up but rather list criteria for well-posed predictions and well-designed prediction tests. The phrase “Guidelines for properly posing and testing earthquake predictions” was felt to capture the intent of the document.

During discussion, questions were raised as to whether rules were too restrictive to deal with non-scientific predictions or even scientific predictions and whether NEPEC should ever consider recommending action based on correlation rather than proven prediction skill. Jackson argued that the field has “spun wheels” due to a lack of rules and rigor in defining earthquake predictions, and gave examples of past predictions that have left ambiguity.

For a prediction considered by NEPEC, four judgments were deemed possible: insufficient demonstration of scientific approach, valid scientific approach, a statement of encouragement for promising lines of research, and finally a need for policy action.

These guidelines are applicable to predictions brought before NEPEC but do not address situations where there is a phenomenon or methodology rather than a prediction brought to the council's attention. There was general agreement that NEPEC should be able to hear about promising research avenues or interesting phenomena and could recommend workshops or encourage USGS to encourage such avenues in its research planning. Such a role constitutes "looking at the horizon" and is consistent with USGS reliance on council members' expert judgment to decide what issues are important to take up in the context of advising the Director on earthquake prediction issues.

Tom Bleier provided a public comment posing the situation where someone is watching phenomena, sees a notable change, and wants a mechanism to declare an unusual event to USGS and/or NEPEC.

It was noted that NEPEC has previously been approached by Koussabukov (SIC) to review his predictions. Having these guidelines on the website creates a space for dialogue on what the council requires and ultimately a basis for deciding whether to schedule a presentation on the council's agenda.

The question was raised how USGS should handle requests to archive predictions and establish track records for phenomena. It was the chair's view that if USGS is going to have a panel like this then USGS needs to maintain a mechanism for those offering predictions to establish a track record. A webform with automated acknowledgement of receipt was suggested as an alternative to logging emails. It was also suggested that SCEC's Collaborative for Scientific Earthquake Prediction (CSEP) project could play a role, although its current focus is limited to seismic data.

[1] NEPEC_eval_crit_CAllen_review.pdf

Action Item (USGS staff): NEPEC asks USGS to come back with a proposal for how it would provide archiving mechanism for predictions and phenomena reports.

Action Item (Dave Jackson; all NEPEC members for comment and approval): Jackson will circulate revised NEPEC Guidelines for Posing and Testing Earthquake Predictions for council comment and approval at which point USGS will post on NEPEC website.

Action Item (USGS staff): USGS will draft statement for council review of what NEPEC will address within its scope for posting on NEPEC website.

Regional Earthquake Likelihood Methods (RELM) Project

Doing double duty, Jackson provided a second presentation on the Southern California Earthquake Center's RELM project. He provided an overview of the project, which has been spearheaded by Ned Field of USGS Pasadena office. A five-year prospective test of nearly a dozen models began on January 1, 2006 and runs until January 1, 2011 with forecasters providing numbers (probabilities of epicenters) for individual grid cells covering California region in order to facilitate comparison and a measure of relative success. A five-year test is for magnitude 5 and greater earthquakes with no updates of predictions allowed; about 12 such tests are underway from January, 2006 (some PI's are likely to submit revised predictions as well). A second test of magnitude 4 and greater earthquakes is updated daily and intended to test foreshock and aftershock models, e.g. STEP and ETAS. (The next day, Tom Jordan clarified that the programming for the daily-update tests had been found to be complex and was not finished). All RELM participants were required to submit papers with modeling assumptions in a special issue of *Seismological Research Letters* due out in January 2007. Models are tested against the long-term prediction represented by the earthquake rupture forecast underlying the California seismic hazard map.

Lessons learned from the RELM experience include that testing is possible but not easy. It requires fairly detailed rules and requires that each investigator provide predictions in a rigidly defined way (at same grid points, same magnitudes, etc.) so that results may be compared. Some methods must be adjusted, or choices made, in order to provide the needed information in the needed format.

SCEC's CSEP project (see below) extends the RELM concept to a broader selection of regions and to larger earthquakes.

In discussion, a suggestion was made that since STEP makes ground-motion predictions, it would be possible to use network of strong-motion instruments to check success of model's 24-hour ground-motion exceedance predictions.

Plans for Pacific Northwest Workshop on Episodic Creep and Tremor

Council member Wayne Thatcher led the discussion with a brief presentation following up on a suggestion made at the council's previous meeting that NEPEC convene a workshop on the societal implications for earthquake prediction of episodic creep and non-volcanic seismic tremor detected in subduction zones and other settings. The presentation focused on a workshop with 40-50 US and international participants to discuss observations, models, research directions, and societal implications.

In discussion, council members expressed interest in first holding a more focused discussion for NEPEC to hear from experts and consider what implications would be of a larger tremor event, recognizing that this is difficult to determine in the absence of understanding the physical mechanism. The utility of having a scale for such events was proposed. The need to learn from the Japanese experience of increased tremor in the Tokai Gap was cited, as was the Mazzotti & Adams paper that estimated the increased probability of a Cascadia-wide earthquake during tremor events, which Zoback distributed electronically[2].

> ***Action Item (input requested from NEPEC members):*** It is proposed that NEPEC hold a 2-day meeting in Seattle in spring 2007 with a day of briefings, a half-day discussion with experts on societal implications and half-day for council to formulate questions to be addressed by larger workshop. Input on this proposal sought from all NEPEC members.
>
> ***Action Item (USGS staff; input also requested from NEPEC members):*** USGS will discuss interest in a larger workshop with potential sponsoring organizations. Conveners need to be identified: council input sought.

Briefing on Ethical and Legal Guidelines (Executive Session)

Dieterich adjourned the meeting for the day at 5:00 p.m.

<u>Tuesday, October 17th (Open Session)</u>

Dieterich called the council to order at 8:40 a.m.

Collaboratory for Study of Earthquake Predictability (CSEP)

Tom Jordan provided an update on progress made on CSEP since his report at the last NEPEC meeting. The focus of the CSEP project, which is funded by a three-year grant from the Keck Foundation, is on developing the scientific infrastructure needed to address the intrinsic predictability of the earthquake rupture process.

To build on the community infrastructure established by CSEP, the Southern California Earthquake Center is proposing a partnership with institutions in Japan, Taiwan, and Turkey to establish additional natural laboratories and multiple testing centers to undertake detailed studies in a variety of regions and fault systems. In January, 2007, an International Conference on Earthquake Predictability and Time-Dependent Forecasting

[2] *Variability of Near-Term Probability for the Next Great Earthquake on the Cascadia Subduction Zone*, by S.Mazzotti & J. Adams, BSSA v5, p1954-1959, 2004 (on NEPEC web site as mazzotti_cascadia.pdf.

sponsored by Swiss Re and SCEC will take place in Zurich, Switzerland. Plans are underway for a National Academy of Sciences symposium on earthquake prediction in January 2008.

Jordan described the management and review structure for CSEP within the overall SCEC structure. He discussed the testing infrastructure, noting that initial tests will draw on RELM-type tests but will also consider fault-based forecasts (like the national seismic hazard map) and accelerated moment release as well as global models. Although head-to-head tests will be done when possible, this more diverse suite of models will be tested against reference models rather than requiring them to compete against one another as with RELM. CSEP will use the University of Southern California's supercomputer center to handle the computational capability required for large-scale simulations.

A key issue facing CSEP, and one that is relevant to NEPEC, is how to connect the goal of addressing the intrinsic predictability of the rupture process with the broader question of the feasibility of useful and operational earthquake prediction. A related issue is how to coordinate CSEP activities with government agencies. Other issues facing CSEP include long-term sustainability, communication with public, and international collaboration.

In response to a question about the potential to expand CSEP to additional non-seismic data streams, Jordan indicated that CSEP would be conservative in its initial phase, concentrating on seismicity-based prediction methods. He noted that establishing the infrastructure for seismicity will be challenging enough from an IT standpoint. Incorporating additional datasets (e.g., geodetic strain) will require additional IT work as well as work by others to define an authoritative and well-characterized data stream.

It was noted in discussion that earthquake catalogs evolve over time (as earthquake locations and magnitudes are refined with additional data), so that a prediction method employing real-time catalog data may yield different results than the same method run using an archival catalog.

Another question raised was the need for automated testing and whether that would be overly restrictive, for example with respect to stress transfer calculations that have, thus far, required a hands-on approach. Jordan noted that we will learn a lot just from trying to test and reiterated that the challenge was to learn how to do rigorous earthquake prediction experiments.

Working Group on California Earthquake Probability – Progress to Date

As with Jackson the previous day, Jordan was asked to perform double duty, giving the first in a series of presentations to inform the council on the current state of progress by the Working Group on California Earthquake Probability (WGCEP) on developing a unified statewide earthquake rupture forecast. Jordan provided the perspective of the Working Group's Management Oversight Committee (MOC), which also includes Rufus Catchings (USGS Menlo Park), Jill McCarthy (USGS Golden), and Mike Reichle (California Geological Survey). The WGCEP is a joint effort of SCEC, USGS, and CGS with major funding from the California Earthquake Authority (CEA). Jordan and Ned Field provided a report to CEA the previous day, which went well. The project has met all deliverable deadlines to date. After providing an explanation of the management

structure and timeline of deliverables, Jordan outlined a series of outstanding issues and associated questions for NEPEC from the Working Group[3]. The moving up by several months of the Building Seismic Safety Committee (BSSC) deadline for delivery of the National Seismic Hazard Map and the attendant shift in deadlines for the Working Group's Earthquake Rupture Model to USGS Golden is the most pressing issue. The major scientific issue for the Earthquake Rupture Model is the "Battle of the Bulge" in which the model diverges from the catalog data, overpredicting events in the magnitude 6-7 range that is particularly critical for hazard assessment. While there are ways to reduce the divergence by tweaking parameters, the current tools available for doing so are not satisfactory and developing better methods (and vetting them through the Scientific Review Committee) will take more time.

Chris Wills from the California Geological Survey (and a member of the WGCEP Executive Committee tasked with carrying out the project) gave a presentation on the deformation model, fault classification, and geologic inputs. The components in the earthquake rupture forecast model include a fault segment database that builds on those developed for the 1996 and 2002 National Seismic Hazard Maps, fault models that represent a complete set of fault segments, and a deformation model that is in turn a fault model with internally consistent slip rate. As has been done previously, faults are classified as A-faults (major high-slip faults), B-faults (significant but do not know enough about slip to generate unique model), and C-faults (zones of distributed shear with defined slip rate and unrecognized faults). The Working Group's selection of A-faults diverges somewhat from that used by the Bay Area Working Group in 2002, and there are several significant changes in A-faults in southern California from previous maps; in particular Wills described how the Working Group was proposing to handle the San Gorgonio section of the San Andreas Fault in an effort to reconcile geologic and geodetic information. He described the approach of defining zones of distributed shear as was used by the 1996 model for eastern California. Part of the “bulge” problem may reflect restrictions on B-fault segmentation that does not allow them to link together in failure, i.e. not allowing large quakes and hence overpredicting moderate ones. A surplus of moderate-length fault segments may be an artifact of the 1996 model. One and possibly two workshops will be held in the next two months to get at this problem and to define the relative rates of motion on A-faults. (Note that Wills’ slide set includes several that he was unable to discuss due to time constraints, including the method used to calculate earthquake rates on segmented A-faults.)

Karen Felzer, a Mendenhall postdoctoral fellow at the USGS Pasadena office, gave a presentation on seismicity rate constraints and her work on the catalog (1850 to 2006) to be used to define the magnitude-frequency distribution of C-zone and background earthquakes and as the observational basis against which the WGCEP model is to be compared. Problems encountered include 1) magnitude rounding that skews the magnitude distribution too high but can be corrected using a Monte Carlo process; 2) magnitude error, in which applying uncertainty again skews the catalog high because there are many more small quakes, the apparent remedy being to apply individual errors but the associated challenge being that of assigning magnitude error for each quake; 3) the incompleteness of the historical catalog and setting a magnitude threshold at which the catalog can be assumed complete in time and space, requiring creative approaches particularly for the earlier parts of the catalog; and 4) the b-value problem, and the

[3] See NEPEC_101706_Jordan_WGCEP_issues.pdf & NEPEC_101706_Jordan_WGCEP_questions.pdf

impact of using a declustered model as in the 2002 National Seismic Hazard Maps. Felzer encouraged the inclusion of error information in earthquake catalogs. She raised questions about the use of a characteristic earthquake hypothesis rather than the Gutenberg-Richter distribution for the magnitude of individual faults and whether aftershocks (and foreshocks) should be included in the time-independent rate calculations. Jordan showed figures illustrating that the ERF underlying the 2002 National Seismic Hazard Maps contained a “bulge” as well.

Mike Reichle of the California Geological Survey made remarks on the recent workshop held by the USGS National Seismic Hazard Mapping Project to obtain user input and develop consensus on the seismic hazard maps for California. This workshop built on previous ones held by WGCEP. Although attendance was somewhat disappointing, there was a good discussion of key issues, including how to handle the Next-Generation Attenuation (NGA) relationships still being developed, whether to include aftershocks (discomfort in the user community), the magnitude-area relations to be used (subject of an upcoming workshop), and an A-fault discussion focused on the San Gorgonio Knot, which would be a major change from the 2002 maps and attendant user concern whether there had been ample review. As mentioned by Wills, one and possibly two additional workshops (the first on November 8 in Menlo Park) will follow to explain and elicit feedback on the fault models and geologic inputs chosen by the working group. At the workshop, Art Frankel (USGS Golden) presented a different approach on how to estimate the cascading of segment-to-segment ruptures based on collected probabilities. With respect to NGA, Reichle noted that the engineering community will be reluctant to use the new maps if the changes are greater than 10 percent, a recognition that should be made but not one that should drive the science. To address the NGA question, USGS convened a separate workshop with a "tiger team" of experts to elicit their judgment on how to proceed given the potential for significant divergence from previous maps and the incomplete nature of some of the NGA models.

Council member Bill Ellsworth made remarks in his role as chair of the WGCEP's Scientific Review Panel, which NEPEC agreed at its previous meeting should be the entity responsible for handling the primary review of the Working Group's products and methods. Ellsworth underscored the challenge represented by the deadline shift, which would necessitate having the Earthquake Rupture Forecast in the review panel's hands by January 2, 2007 in order to allow a couple of weeks for review and then time for the WGCEP Executive Committee to respond to the review with changes as appropriate and get results to the USGS Golden group in time for them to meet the February 15, 2007 BSSC deadline. Ellsworth recapped the issues: slip rate models, documentation of ruptures, segmentation of A- and B-faults, how to treat multi-segment ruptures, how geologic insight should be used to shape models, the magnitude bulge issue (currently models assume fully locked faults, not creep), and uncertainty and the use of expert opinion. He described the review process so far as less formal, emphasizing dialogue but not resulting in a formal review process within USGS; the next stage needs a formal review process. He posed the question whether NEPEC wishes to make a recommendation to the USGS Director on the scientific quality of the time-independent ERF. The broader issue raised by this question is whether NEPEC intends to play a review role in the National Seismic Hazard Map itself, a step not previously taken (and a position that did not receive enthusiastic discussion in previous NEPEC discussions).

Council member Bruce Shaw noted that it seems we are in a transition time with the science, trying to find workaround solutions to problems that we are developing the tools

to address, and asked whether it was possible to shift to a later building code revision or try for a more frequent revision schedule of the seismic hazard maps. Wills commented that no matter what the schedule, hazard products will inevitably rely on imperfect solutions to complex issues. Ellsworth noted the likelihood that we will eventually abandon the concept of strict fault segmentation, and that there's a need for procedures that moderate the inclusion of new ideas into hazard mapping lest they erode acceptance within the engineering community.

> ***Action Item (USGS staff):*** USGS will obtain more clear guidance from the BSSC on how fixed the model delivered to meet the February 2007 deadline must be or whether there is the possibility for limited revisions subsequent to that date in an iterative process.

The ensuing discussion was structured on the questions posed by Jordan:

Question #1: What degree of "publication" should be required for the underlying components of the model; i.e., what flexibility should be allowed with respect to the standards and dates outlined above?

The council agreed that because the WGCEP effort represents a high-impact piece of work with major policy implications, it is important that the information upon which the model is based (e.g., fault slip rates) be reviewed and visible to the public, even if the mechanism is a preliminary document such as a USGS open-file report. Undocumented scientific work is not ready for public policy application. Wills noted that efforts are underway to compile what is known on the Southern San Andreas Fault and the San Jacinto in an effort to better document the state of knowledge. It was suggested that there be a publication that states how unpublished data (e.g. consultant reports) were used in development of the model. Jordan indicated that the MOC would request an inventory of data products needed.

In subsequent discussion Jordan explained the MOC's position that "novel data products" (such as Karen Felzer's new earthquake catalog) be reviewed and published separately so that it can be referenced in the Working Group report. "Novel model components" (e.g., a new magnitude-area treatment) will appear as appendices to the Working Group document and will reviewed separately as well.

Question #2: Does NEPEC agree to review the WGCEP products for the USGS National Seismic Hazard Mapping Project during January, 2007?

It was not clear from previous discussions that a NEPEC review of the time-independent earthquake rate model was required or to be sought. Dieterich cautioned that the tight schedule would require such a review to consist of little more than a "thumbs-up/thumbs-down."

> ***Action Item (NEPEC members):*** Council members are asked to comment on proposed review approach by which a NEPEC subcommittee participates in the Scientific Review Panel's review in January and then makes a recommendation to the full council, which may meet by teleconference rather than face-to-face; volunteers are also sought for service on the subcommittee.

Action Item (USGS staff): USGS is to decide whether to ask NEPEC to provide a review of the earthquake rate model.

Question #3: To what degree should the model used for the USGS hazard map update for California correspond with the WGCEP earthquake rate model? Should they be one and the same or is some divergence appropriate or even potentially necessary?

Reichle pointed out that having separate models makes it difficult to defend any individual one. He suggested defining the state of the model at discrete points in time, delivering the best science possible as of January 2007 for the national map deadline or August 2007 for the CEA deadline. Jordan argued that it is in the best interest of all to negotiate with BSSC in order to maintain coherence among models.

It was noted that while the California Earthquake Authority's threshold was "best available science", they were also eager to have concurrence of models as an indication of robustness and consensus. The biggest concern is the bulge problem, placing a high priority on getting that right and seeing it dealt with in an appropriate and defensible manner.

Action Item (NEPEC Chair and USGS staff): Draft a letter to USGS Director emphasizing concern about the effect of the BSSC deadline shift and its implications for coherence of products delivered for California.

Question #4: Does NEPEC agree to review the WGCEP products for the California Earthquake Authority during August, 2007? If so, should a special NEPEC/CEPEC/SRP meeting be scheduled for this review, perhaps as a one-day session of Workshop 10?

The council deferred discussion of this question until the issues raised in Question #2 have been resolved and indeed the experience of dealing with the review of the products for the National Seismic Hazard Map has been considered in terms of what is realistic for NEPEC to do. Several council members emphasized that they were not comfortable being put in the position of rendering an up-or-down recommendation as is required by the temporal constraints in NSHM delivery.

Superstition Hills Creep Event

Ken Hudnut from the USGS Pasadena office provided the council with a brief presentation on the recent creep event on the Superstition Hills fault as recorded by cross-fault extensometers deployed by Roger Bilham at the University of Colorado. The Superstition Hills fault is the southernmost section of the San Jacinto fault zone, and its substantial creep since the 1987 M6.6 earthquake has been well recorded by R.V. Sharp and others. The current sequence of small creep episodes total about 26 mm thus far, representing the second time that >25 mm of creep has accumulated in one event set. Bilham and colleagues have demonstrated that the creep events within a set are both time- and slip-predictable.

Recent seismicity in the area does not appear to be anomalous, and there does not seem to be any close association between the creep and earthquakes within the region, or with any transients seen on other instruments nearby. Hudnut noted the lack evidence from GPS or strain data that the observed creep is associated with deep-seated fault

slip; while modeling of deep motions has not yet been done, he estimated that no more than 5 cm of slip could have accumulated on a deep, vertical fault. In discussion, Hudnut explained that observations were consistent with the model proposed by Chris Marone and Chris Scholz, in which deep, seismic slip (roughly one meter in this case) is followed by shallow, exponential creep as the near-surface portion of the fault "catches up" during the interseismic period.

Adjournment

After a brief review of action items and potential dates for a NEPEC telecon and an SRP-WGCEP workshop, and a reminder that input is needed on expertise for the council, Dieterich adjourned the meeting at 12:00 p.m.

Meeting summary by D. Applegate, edited by M. Blanpied